

What is claimed is:

1. An optical element having a substrate formed by  
an optical material,

said substrate comprising:

5 a convex part functioning as a convex lens;  
a flat part positioned around said convex part;

and

an outer circumference part positioned around  
said flat part, wherein

10 a thickness of said outer circumference part is  
greater than that of said flat part,

whereby the mechanical strength is improved and  
the resonance frequency is increased.

2. An optical element as set forth in claim 1,  
15 wherein the thickness of said outer circumference part is  
greater than that of said convex part.

3. An optical element as set forth in claim 1,  
wherein said substrate comprises a first groove formed at  
a boundary between said convex part and said flat part,  
20 for defining a region of said convex part.

4. An optical element as set forth in claim 3,  
wherein said substrate comprises a second groove formed  
at a boundary between said flat part and said outer  
circumference part, for defining a region of said flat  
25 part.

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5. An optical element as set forth in claim 1,  
wherein said optical material comprises fused silica.

6. An optical element as set forth in claim 1,  
wherein a surface of said outer circumference part is  
5 flat or approximately flat and thereby holding is eased.

7. An optical element as set forth in claim 1,  
wherein a plurality of steps are formed at said outer  
circumference part, the thickness of said substrate at an  
outer side step is thicker than that of said substrate at  
10 an inner side step, and thereby eclipse is prevented.

8. An optical element having a substrate formed by  
an optical material,

15 said substrate comprising:  
a convex part functioning as a convex lens;  
a flat part positioned around said convex part;  
an outer circumference part positioned around  
said flat part;

20 a first groove formed at a boundary between  
said convex part and said flat part, for defining a  
region of said convex part; and

a second groove formed at a boundary between  
said flat part and said outer circumference part, for  
defining a region of said flat part, wherein  
25 a thickness of said outer circumference part is  
greater than that of said flat part;

both said flat part and said outer circumference part comprise flat shapes in the thickness direction; and

5       said convex part, said flat part, and said outer circumference part are integrated in a unit by said substrate.

9.      An optical element having a substrate formed by an optical material,

10     said substrate comprising:  
          a convex part functioning as a convex lens;  
          a flat part positioned around said convex part;  
          an outer circumference part positioned around  
          said flat part; and  
          a groove formed at a boundary between said  
15     convex part and said flat part, for defining a region of  
          said convex part, wherein  
          a thickness of said outer circumference part is  
          greater than that of said convex part;

20     both said flat part and said outer circumference part comprise flat shapes in the thickness direction; and  
          said convex part, said flat part, and said outer circumference part are integrated in a unit by said substrate.

25     10. An optical element having a substrate formed by

an optical material,

said substrate comprising:

a convex part functioning as a convex lens;

a flat part positioned around said convex part;

5 a first outer circumference part positioned

around said flat part;

a second outer circumference part positioned  
around said first outer circumference part;

10 a third groove formed at a boundary between  
said convex part and said flat part, for defining a  
region of said convex part; and

a fourth groove formed at a boundary between  
said flat part and said first outer circumference part,  
for defining a region of said flat part, wherein

15 a thickness of said first and second outer  
circumference parts are greater than that of said flat  
part and the thickness of said second outer circumference  
part is greater than that of said first outer  
circumference part;

20 all said flat part and said first and second  
outer circumference parts comprise flat shapes in the  
thickness direction; and

said convex part, said flat part, and said  
first and second outer circumference parts are integrated  
25 in a unit by said substrate.

TOTAL PAGES: 01

11. A method for producing an optical element comprising the steps of

forming a first mask layer and a second mask layer surrounding said first mask layer on a substrate  
5 formed by an optical material;

heat treating said first mask layer to form it into a convex lens shape; and

etching said substrate to transfer said convex lens shape of said first mask layer to said substrate.

10 12. A method for producing an optical element as set forth in claim 11, wherein the step for forming said first and second mask layers comprises patterning a mask layer formed by a photosensitive material on said substrate to form said first and second mask layers.

15 13. A method for producing an optical element as set forth in claim 11, wherein, in the step for heat treating said first mask layer to form it into a convex lens shape, the heat treatment temperature is higher than a glass transition temperature of said first mask layer.

20 14. A method for producing an optical element as set forth in claim 11, wherein, in the step for heat treating said first mask layer to form it into a convex lens shape, the heat treatment temperature is lower than a carbonization temperature of said first mask layer.

25 15. A method for producing an optical element as

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set forth in claim 11, wherein, in the step for heat treating said first mask layer to form it into a convex lens shape, the heat treatment temperature is higher than room temperature or ordinary temperature.

5        16. A method for producing an optical element as set forth in claim 11, wherein:

the step for forming said first and second mask layers comprises forming said second mask layer having an opening part, then forming said first mask layer at said  
10      opening part; and

            said second mask layer is formed by an etching-resistant material.

17. A method for producing an optical element as set forth in claim 11, wherein:

15        said second mask layer comprises  
            a third mask layer formed by an etching-resistant material and

            a fourth mask layer superposed on said third mask layer so as to cover said third mask layer on said  
20      substrate; and

            said fourth mask layer is formed by the same material as said first mask layer.

18. A method for producing an optical element as set forth in claim 11, wherein

25        said substrate is formed by fused silica,

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said first mask layer is formed by an optically transparent material having a good characteristic for forming a thick film, and

said second mask layer is formed by platinum.

5 19. A method for producing an optical element as set forth in claim 17, wherein

said third mask layer is formed by platinum and said fourth mask layer is formed by an

10 optically transparent material having a good characteristic for forming a thick film.

20. An optical pickup comprising:

an optical element functioning as an object lens when mounted on a recording and/or reproducing apparatus of an optical storage medium and

15 a photodetector for receiving a reflected light beam for use in recording and/or reproduction to and from the optical storage medium,

the optical element comprising a substrate formed by an optical material,

20 the substrate comprising

a convex part functioning as a convex lens,

a flat part positioned around the convex part,

and

an outer circumference part positioned around

25 the flat part,

a thickness of the outer circumference part being thicker than that of the flat part to thereby improve mechanical strength and increase a resonance frequency.

5        21. An optical pickup as set forth in claim 20, wherein the thickness of said outer circumference part is greater than that of said convex part and thereby the mechanical strength of said optical element is improved and the resonance frequency of said optical element is  
10        increased.

22. An optical pickup as set forth in claim 20, wherein a surface of said outer circumference part is flat or approximately flat and thereby holding of said optical element is eased.

15        23. An optical pickup as set forth in claim 20, wherein a plurality of steps are formed at said outer circumference part, the thickness of said substrate at an outer side step is greater than that of said substrate at an inner side step, and thereby eclipse is prevented.

DRAFTS PENDING EXAMINATION